Probing Cosmological Constant Through the Alcock-Paczynski Test Based on the Lyman-Alpha Forest

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Alcock-Paczynski Test :

- For a spherical object (which follows the Hubble flow) in the sky, its physical size along the line of sight and perpendicular to the line of sight should be the same.

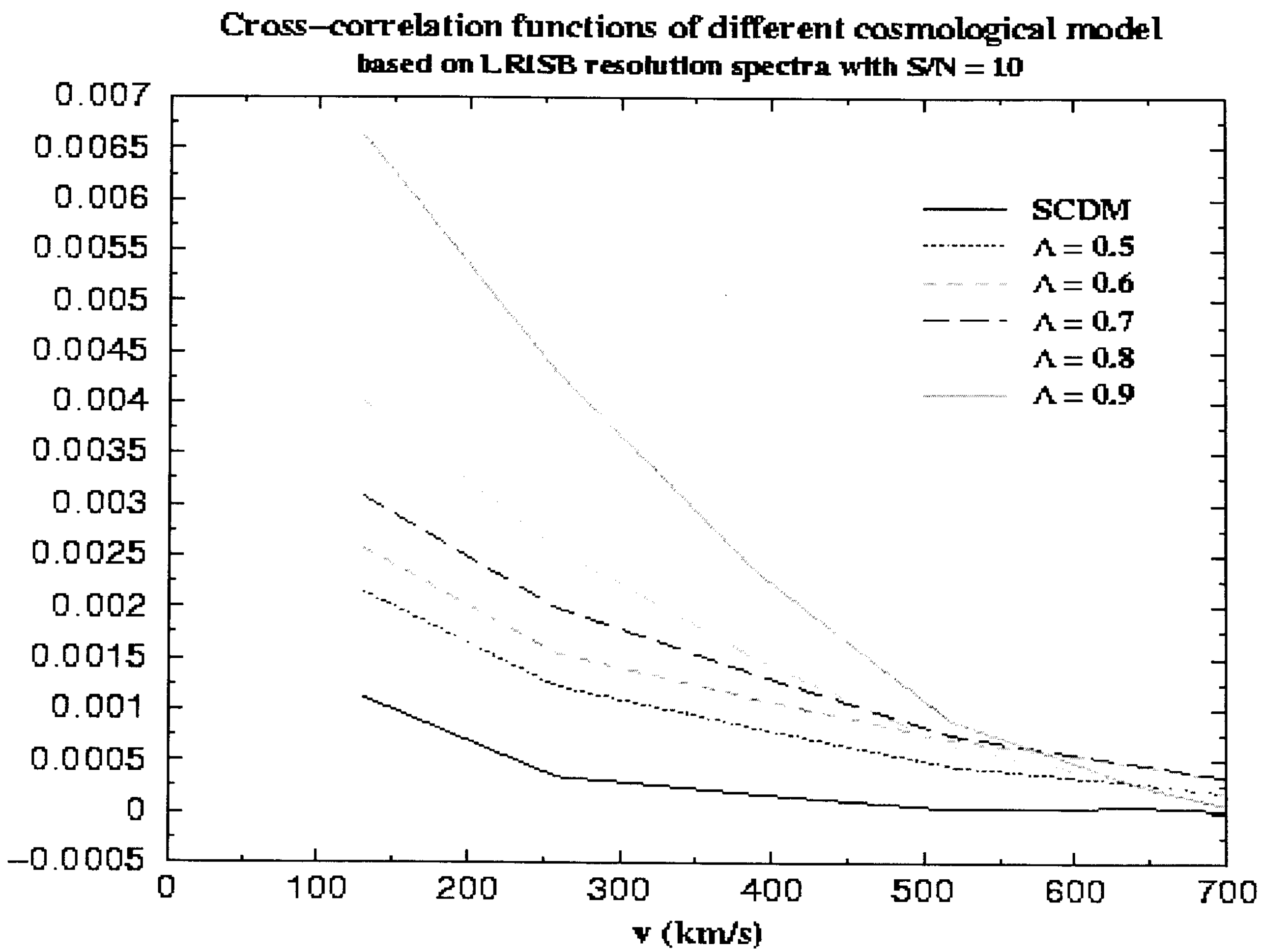
- For a non-spherical structure like Lyman-Alpha forest, we use the correlation function instead of the physical size.

- **The cross-correlation function is most sensitive to Ω_Λ**

Methodology :

- Use paired QSO spectra to provide real cross-correlation functions of our Universe.
- Use simulations to provide correlation-functions in different cosmological models (different Ω_Λ).
- Combine observational data and simulations to derive Ω_Λ .

Cross-correlation Functions For Different Cosmological Models



Major Difficulties and Solutions :

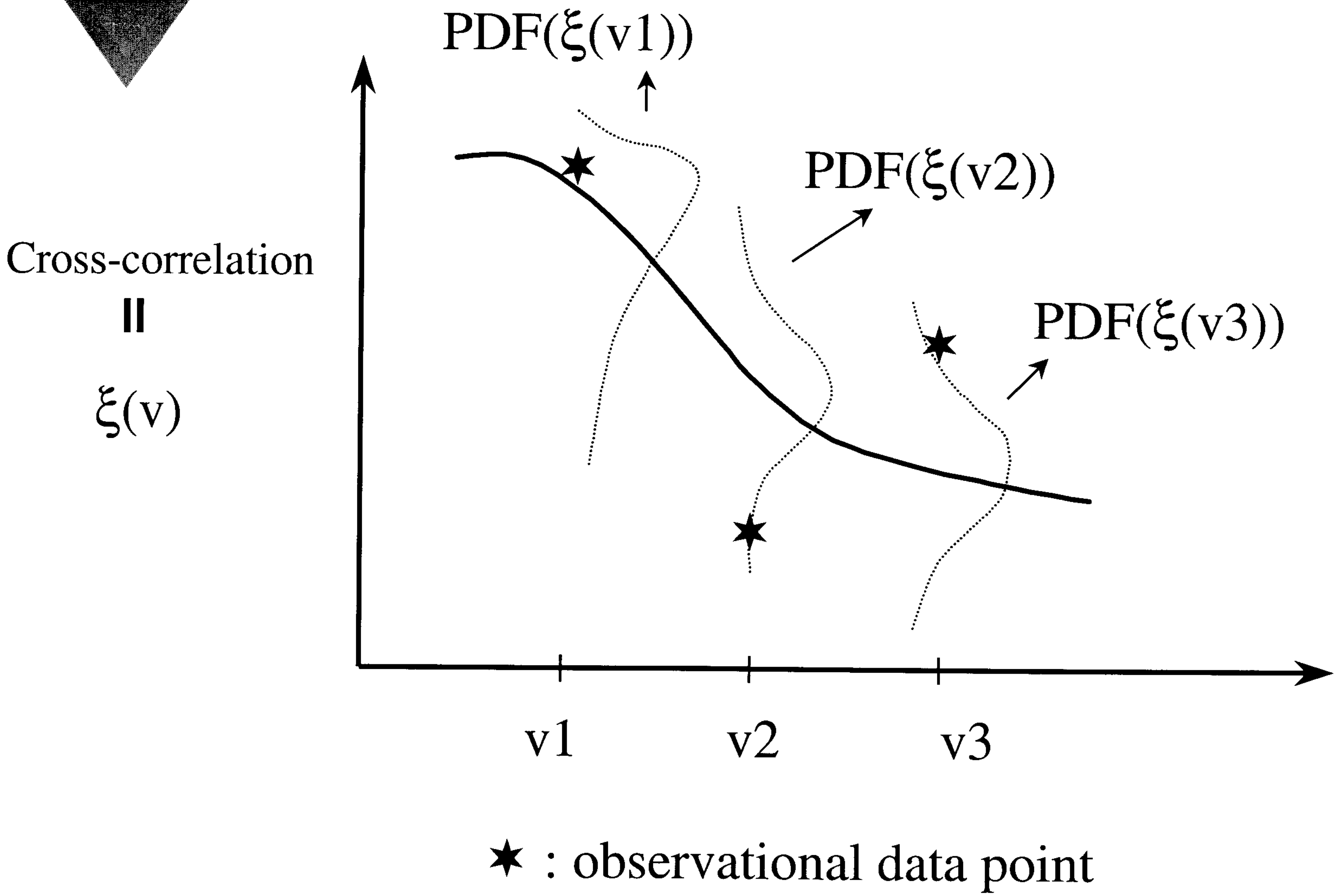
- Cosmic Variances :

  Introduce the **maximum likelihood estimation**.

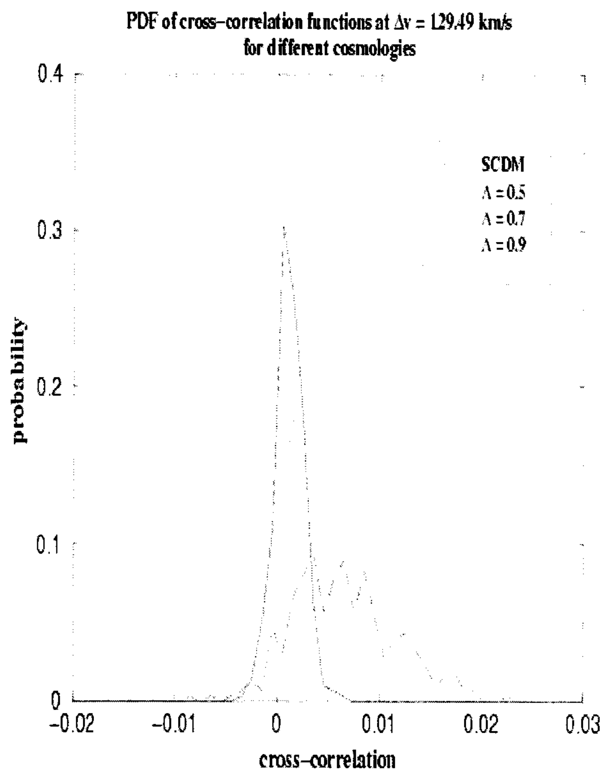
- Signal- to - noise (S/N) properties :

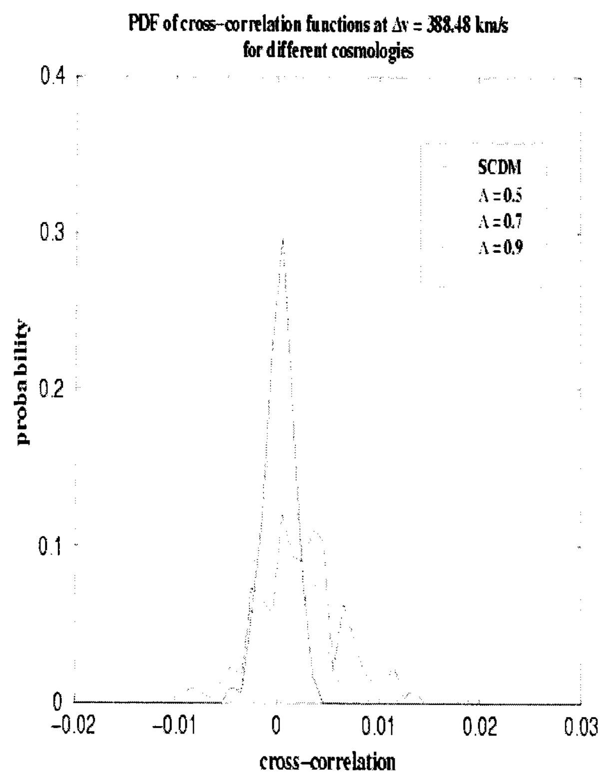
  Generate artificial QSO spectra with different kinds of signal- to - noise properties for our study.

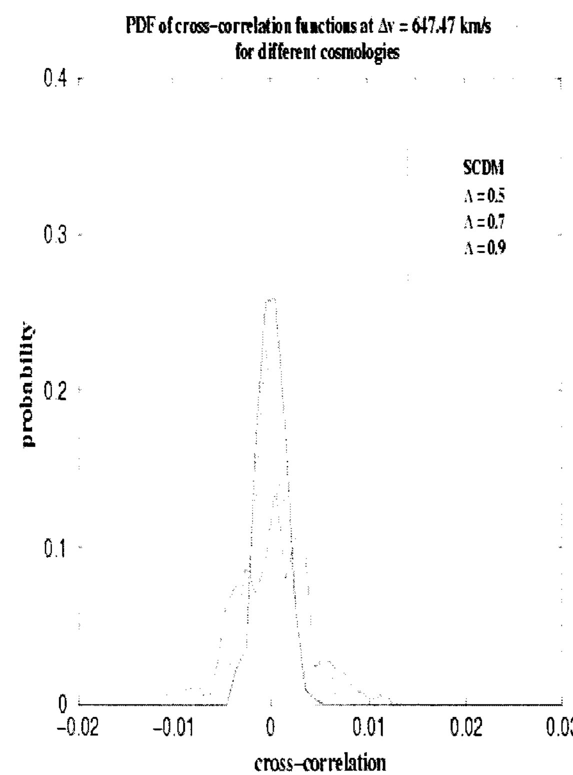
Maximum Likelihood Estimation :



Probability Distribution Functions at Different velocity separations







Procedures :

- Simulations provide PDF($\xi(v)|\ \Omega_\Lambda$) at each v for different cosmological model.
- Take simulated QSO spectra in $\Omega_\Lambda = 0.7$ simulations and pretended they were observation data.
- Then we can calculated the combined-likelihood based on all the data points we have :

[redacted]

where x_i are fake observation data points and the corresponding PDF are provided by our simulations.

- Maximizing the likelihood function **L** (Ω_Λ) to determine Ω_Λ

Conclusions :

- With 30 pairs of QSO spectra we have more than 60% probability to determine Ω_Λ within 10% error and more than 90 % probability to obtain Ω_Λ within 20% error.
- QSO spectra with S/N ≥ 20 are required to achieve the above results.

TABLE 1

PROBABILITY OF GETTING Λ WITHIN 10 % ERROR

pairs/group	group#	Results of Ω_Λ	Prob(20%)	Prob(10%)	Prob(5%)
10	30	$\Omega_\Lambda = 0.6 \pm 0.145$	55.97 %	29.76 %	15.11 %
15	20	$\Omega_\Lambda = 0.6 \pm 0.104$	63.93 %	33.55 %	16.89 %
20	15	$\Omega_\Lambda = 0.64 \pm 0.1$	76.54 %	44.31 %	23.03 %
25	12	$\Omega_\Lambda = 0.7 \pm 0.11$	79.69 %	47.55 %	24.97 %
30	10	$\Omega_\Lambda = 0.7 \pm 0.074$	94.15 %	65.56 %	36.38 %